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NMRI 97-01 February 1997

Quantification of Special Operations Mission-Related Performance:

Operational Evaluation of Physical Measures

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NMRI 97-01

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
January 6, 1997

3. REPORT TYPE AND DATES COVERED
Technical, 1/94-10/96

4. TITLE AND SUBTITLE
Quantification of Special Operations Mission-Related Performance: Operational Evaluation of Physical Measures

5. FUNDING NUMBERS
PE - 1160407B
PR - 407BB
TA - 001
WU - 1314

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Commanding Officer
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8. PERFORMING ORGANIZATION REPORT NUMBER
NMRI 97-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Medical Research and Development Command
National Naval Medical Center
Building 1, Tower 12
8901 Wisconsin Avenue
Bethesda, Maryland 20889-5606

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The United States Special Operations Command (USSOCOM) has identified a need for standardized measures to quantify mission-related performance when conducting research in the Special Operations community. Based on operator input, five measures of physical performance were selected to be evaluated. The five tests are 1) maximal handgrip strength and endurance, 2) maximal number of pull-ups, 3) maximal number of repetitions during a timed step test, 4) manual dexterity, and 5) shooting skills. Measures 1-4 were evaluated during various training scenarios: winter and land warfare, high speed boat and Sea, Air, Land (SEAL) Delivery Vehicle (SDV) operations, and parachuting. The shooting skills test is currently being evaluated. A total of 30 operators volunteered to participate. Baseline measurements were established on all operators. Post-operation measurements were compared to baseline to quantify changes in performance. Changes were related to the different stressor conditions, therefore resulting in multiple patterns of change rather than a single pattern related to all stressor conditions. Selective decrements in

14. SUBJECT TERMS
Physical measures, Physical Stress, Thermal stress, Operational environments

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

13. performance must be evaluated by operators with respect to any potential impact on mission success. Continued evaluation of the test battery will further refine the sensitivity of the measures to changes in mission-related performance of Special Operations personnel.

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ACKNOWLEDGMENTS

This work was supported by the Special Operations Command Work Unit Number 1160407B.407BB.001.1314. The opinions and assertions expressed herein are those of the authors and are not to be construed as official or reflecting the views of the Department of Defense, the United States Special Operations Command, the Department of the Navy, or the Naval Service at large.

The research protocol employing human subjects in this study has been reviewed and approved by the Naval Medical Research Institutes's Committee for the Protection of Human Subjects.

INTRODUCTION

Environmental stressors can have a significant impact on the mission performance of Special Operations Forces (SOF). Successful completion of mission objectives may be threatened by the effects of exposure to a variety of extreme stressors. The United States Special Operations Command (USSOCOM) sponsors research efforts designed to understand and minimize the effects of such stressors on mission performance. To provide an important platform of support for these research efforts, USSOCOM has issued tasking designed to standardize performance measures to be used in laboratory and field research studies. Standardization of measures would enable stress-induced changes in performance to be more accurately and reliably quantified, therefore enhancing the ability of SOF biomedical research to provide operationally relevant results. Standardization would also provide operators with information useful in operational planning and would simplify comparison of data obtained by various biomedical research facilities.

This report is concerned with measures of physical performance. A variety of sources were utilized to identify tasks relevant to mission-related performance. Feedback from experienced operators has resulted in a compilation of physically demanding activities performed during missions by SOF personnel (1,2). A Naval Special Warfare (NSW) Thermal Workshop solicited the input of experienced operators and specialists in the area of performance measurement (3). In addition, information concerning the physical performance and capabilities of SOF personnel during mission-related activities has provided insight into the effects of the extreme stresses faced by operators (4,5,6,7). The physical demands and capabilities of SOF personnel were not the only criteria used to select physical measures sensitive to changes in

performance. In many cases these measures need to be conducted under less-than-favorable remote field conditions. Constraints of possible field environments dictate that the components of any system be 1) extremely portable, 2) adaptable to varied environments, 3) easily administered under rugged field conditions, 4) capable of collecting data in a reliable and unbiased manner, and 5) perceived by the operators as functionally relevant to their operational scenarios. An inability to relate the test measures to physical components that affect operator mission performance will result in less-than-maximal efforts by research subjects and the collection of inaccurate data.

The focus of this research is the validation of a selected battery of physical tests in operationally stressful environments. Critical aspects of this validation relate to the sensitivity and reliability of these measures to the impact of extreme stressors on mission-related performance. Data were collected under a wide range of operationally stressful field environments in order to quantify any observed changes in performance. This report describes the specific operational environments examined to date and provides data obtained with the selected physical measures in those environments.

PROCEDURES AND RATIONALE

Based on the above-listed criteria, five tests were selected to evaluate strength, endurance, fine and gross motor skills, eye-hand coordination, and vision. The measures selected were 1) maximal pull-ups, 2) maximal repetitions during a timed step test, 3) maximal handgrip force, 4) disassembly and reassembly of a weapon, and 5) shooting skills test. Measures 1-4 have been evaluated during multiple operational scenarios. The shooting skills test is currently being evaluated during training operations.

In an effort to represent a wide variety of operational environments, multiple SOF units were contacted about participation in this project. Units responding were each planning to conduct a Field Training Exercise (FTX) that could be incorporated into this validation study. The various FTXs involved Winter Warfare, Land Warfare, High Speed Boat, Parachute and Sea, Air, Land (SEAL) Delivery Vehicle (SDV) operations. Potential subjects in each respective unit were briefed on the purpose of the USSOCOM tasking, the components of the performance assessment system, and the time requirements as a result of their participation. Volunteers were solicited to participate in the project and signed informed consent forms. A total of 30 operators volunteered to participate. Data were collected both before (Baseline) and after (Post-FTX) the scheduled training operations.

Baseline Data Collection

The tests involving physical measures of performance were designed to require minimal training prior to baseline data collection. Proper technique was demonstrated and the operators familiarized themselves with the testing equipment. The complete battery of physical tests took approximately 15 min to complete. Accuracy of baseline data is of paramount importance to the successful comparison with post-FTX data and the determination of any effect of the FTX on mission performance. Therefore, baseline data must be collected at least twice, or as many times as necessary to establish repeatability and ensure accuracy of the results. Baseline data were collected during times when operators were engaged in a routine that does not include the stressful conditions being investigated. The tests are listed below in the order in which they were performed both before and after operational exercises.

1) Manual dexterity

This test is designed to evaluate fine and gross motor skills of the fingers, hands, and arms. Disassembly and reassembly of a weapon were selected as appropriate tasks, based on the knowledge that all operators would have prior experience with field-stripping a weapon. Adequate re-familiarization and consistent performance with the weapon were established prior to the task being performed for a recorded time. Operators disassembled and reassembled either an M-16 (Model 727, carbine, 5.56 mm) or an HK-MP5 (Navy Model, submachine gun, 9 mm), depending on personal preference. The task was timed either by an investigator using a stopwatch or by a timing device connected to a computer that was activated to indicate the beginning of the disassembly and the end of the reassembly. The level of disassembly was established prior to the training exercise and entailed field-stripping the weapon.

2) Maximal handgrip strength and endurance

A hand dynamometer was used to evaluate hand and forearm muscular strength. Proper adjustment and use of the instrument was demonstrated to the operators. They were instructed to first grasp the instrument and allow the hand and arm to hang at their side. After this position was attained, they were instructed to squeeze the dynamometer as hard as possible, thus exerting a maximal contraction of the hand. Maximal hand grip strength was recorded from the dial indicator on the dynamometer. Depending on performance concerns, measurements were made on one hand (typically the dominant hand) or both hands. If differences are encountered in the level of stress each hand could be subjected to, then data should be collected from both hands. Data included in this report concern only measurements of maximal hand grip strength. Future

data collection will include a measure of endurance. The following steps outline the procedure that will be used to quantify endurance:

a) A digital output on the dynamometer is connected to a lap-top computer, thus allowing a real-time display of the dynamometer output on the computer screen.

b) Once maximal handgrip force is established, values equal to 45 and 55% of maximum are automatically calculated by the computer. These values comprise a lower and upper limit "window," which is displayed in real time on the computer screen.

c) The operators are instructed that once a maximal force has been generated, they are to relax their contraction until it is within the 45-55% window and maintain that level for as long as possible.

d) The amount of time the contraction is maintained within the window is recorded automatically by computer as a measure of endurance.

3) Upper body strength

Operators were instructed to perform a maximal number of pull-ups. This task was chosen to quantify strength during a high-intensity exercise for a combination of muscle groups in the upper body. Operators had previously been briefed on the proper technique and use of a portable pull-up apparatus. At all times during the task subjects were flanked on each side by a safety spotter in the event that they slipped from the bar or they must descend a short distance to the ground after release from the bar. The maximal number of pull-ups was recorded by computer.

4) Lower body mobility, coordination, and strength

Operators were asked to mount and dismount a set of steps as many times as possible for a period of 30 sec. Proper technique was demonstrated during the briefing prior to the training exercise and operators were allowed to familiarize themselves with the procedure. The number of cycles was recorded by computer as an indicator of lower body mobility, coordination, and strength. In addition to the results contained in this report, additional data collection indicated that changes in mobility and coordination could be subjectively observed during post-FTX testing, but there was no observed effect on the number of cycles completed by the operator. Subsequently, the length of the step test was increased to 60 sec. Results of this increase in time and any effect on test sensitivity will be reported at a later date. Additional variations of the step test that are of interest to operators and would relate to specific operational scenarios will be incorporated into future testing. These variations include the wearing of specific gear, adding a specific amount of weight to represent a mission-relevant load, or adding weight as a percentage of body mass. Subjects were flanked by safety spotters during the performance of the task. The steps used are of the standard Harvard Step Test variety (two steps, each ten inches in height, for a total of twenty inches vertical rise).

5) Shooting skills

While this portion of the test battery has recently been brought on line and evaluation has not yet been completed, a short description of the apparatus and procedures is included in this report. Specially modified weapons (M-16s or HK-MP5s) are used to assess the ability of subjects to quickly acquire and hit a series of pop-up targets. Weapons were modified to operate pneumatically (no ammunition or blanks were used) using a portable pressurized gas system (gas

supplied by SCUBA tanks) in a semi-automatic firing configuration. The firing of a shot is simulated by a laser system activated by the trigger pull of the weapon. Reflective targets return the laser beam to the receiver on the weapon if a hit is scored. Recorded data include the number of targets hit, the total number of shots fired, identification of targets that are hit, the elapsed time from presentation of a target until it is hit by a shot from the weapon, and the order of target presentation. Scripts can be written to provide specific patterns of target presentation (duration of presentation, the interval between targets, and order of presentation) relating to specific operational scenarios. Specific placement of the targets can be varied depending on specific interests of the SOF unit(s) participating in the performance testing. Scoring will be recorded automatically by a computer remotely connected to the weapon.

POST-OPERATION TESTING

Testing after the FTX had been completed took place as quickly as possible, and in most cases within 10 min. Consultation between training personnel and investigators determined the appropriate location and time during which post-FTX testing took place. Test sequence was in the same order as baseline testing.

DATA ANALYSIS AND PRESENTATION

Data collected during all operational environments except SDV dives and safety boat runs were pooled and compared pre- versus post-FTX, using means $\pm$ SEM. Comparison was made using a paired t-test with statistical significance accepted at the $p<0.05$ level. Pre-FTX data were presented as a baseline value, with post-FTX data represented as a percentage of baseline. Statistical significance was determined using means of the pooled data. Due to the small sample

size and multiple gas mixtures, data for SDV dives and safety boat runs were not pooled and were presented by comparing the post-FTX data to baseline results for each individual.

OPERATIONAL ENVIRONMENTS

Winter Warfare Training

Evaluation of the physical measures during winter warfare training was conducted with members of SEAL Team 2. Sixteen individuals volunteered to participate. Baseline data were collected prior to field deployment in January 1995 at the Naval Amphibious Base (NAB), Little Creek, VA. Winter warfare training took place at Elmendorf Air Force Base, Anchorage, AK. During February 1995 the volunteers engaged in continuous FTX in a remote location (Arctic Valley), for three days and two nights. The FTX involved ski treks through heavy snow conditions and various operational scenarios. Air temperature ranged from +5 to -15 °F.

Post-FTX measures were obtained on Day 3 (at approximately 1700 hours) at the remote extraction site. Only 13 operators were tested due to early extraction of 3 operators for treatment of cold-weather injuries. Operators performed the physical tests immediately after finishing their final ski trek (approximately 1200 foot rise over one-half mile). Air temperature ranged between 0 and +5 °F during the post-FTX measurements. Time requirements were less than 10 min per subject.

Land Warfare Training

Of the 16 operators from SEAL Team 2 who had volunteered to participate in the evaluation during winter warfare training, 8 were scheduled to participate in land warfare training and consequently volunteered to participate a second time. These eight operators were involved in a training exercise at Fort Pickett, VA in May 1995, which continued for two days

and two nights. The eight operators participated in a large-scale multi-unit exercise that involved rapid overland treks, high levels of physical activity and significant sleep deprivation.

Post-FTX measurements were obtained at the beginning of the third morning (at approximately 0100 hours). The operators had been extracted by helicopter and deposited at the test site within several minutes. Again, the time requirement for performance of the physical tests was less than 10 min per subject.

High-Speed Boat Operations

Operators were recruited from Green/Gray training group, Naval Special Warfare Development Group (NSWDG). Baseline data were obtained during April 1995 in Dam Neck, VA. Operational measurements were also obtained twice in April 1995 in conjunction with a 5-day high-speed boat training operation that commenced in Virginia Beach, VA and ended in Jacksonville, FL. During the training operation all individuals rotated among the three boat positions of driver, throttleman, and navigator. When not occupying one of these positions, operators rode in the rear of the boat as passengers.

Performance measures were obtained at the approximate midpoint of the trip on the third day in Georgetown, SC. Data were collected at a pre-determined site within 10 min of docking (at approximately 1400 hours). Rough weather conditions were common during the first three days, resulting in three out of seven boats being severely damaged and rendered unserviceable.

Performance measures were obtained on the fifth day (at approximately 1300 hours) when the boats reached Jacksonville, FL. Weather conditions during the last 2 days were less severe than during the first 3 days.

Parachute Operations

The same eight operators from Green/Gray NSWDG who participated in the high-speed boat operations volunteered to evaluate the physical performance measures during parachute operations. Data were obtained during May 1995 at a training site near Marana, AZ over a period of several days. Training consisted of both day and night jumps involving a variety of altitudes and equipment configurations. Jumps during daylight hours were subjectively considered by the operators to be relatively low stress operations (even when multiple jumps per day were involved). Night jumps, especially high-altitude high-opening (HAHO), were subjectively considered to be more stressful.

Performance measures were obtained twice during this training schedule. Once during the early afternoon (at approximately 1300 hours) after the third jump of the day and once during the early morning (at approximately 0400 hours) following a HAHO jump (18,000 ft). Measurements were obtained within 5 min of landing and de-rigging.

SDV Operations

Twelve SDV operators from the British Royal Marine Special Boat Service (SBS) Support Squadron volunteered to evaluate the physical performance measures. Baseline data were obtained during February 1995 at a training site near Trömso, Norway. Operational data were obtained during February 1995 following a series of SDV training dives in the fjords near Trömso. Water temperature during the dives was consistently 34°F and air temperature ranged from +8 to +14°F. Two operators were involved in each SDV dive, either as a pilot or a navigator. The dives lasted up to 5 hours. Operators used a closed-circuit breathing apparatus with a gas mixture of 60% nitrogen/40% oxygen (60/40) or 79% nitrogen/21% oxygen (AIR) and

wore custom-fitted cold-water diving ensembles. Additional individuals who volunteered to evaluate the performance measures were members of the surface craft that served as the safety boat. This craft consisted of a semi-open cockpit rigid inflatable boat (RIB) that tracked the SDV during all training dives. Crew members of the safety boat were subjected to surface environmental conditions for the duration of any SDV operation. Performance measures were obtained as quickly as possible following surfacing of the SDV and de-rigging of the operators. Generally, measures were obtained within 10 min of surfacing.

RESULTS OF OPERATIONAL EVALUATION

Data collected to date are represented by Figures 1 through 12. All measurements completed before operational exercises were considered baseline data. Measurements completed after termination of operational exercises (post-FTX) were normalized to baseline and are represented as a percentage of baseline. Significant differences between baseline and post-FTX data are calculated based on the absolute mean values of the data.

Winter Warfare

When compared with baseline data, performance measurements made after the winter warfare FTX in Anchorage, AK were significantly different in three of four cases (Fig. 1). Manual dexterity was impaired ($p < 0.01$), handgrip strength and the number of pull-ups were reduced ($p < 0.05$ and $p < 0.01$, respectively). Step test data show no differences between baseline and post-FTX measurements.

Land Warfare

Performance measurements obtained after the land warfare exercise at Fort Pickett, VA exhibited a different pattern compared with winter warfare data (Fig. 2). Manual dexterity was

again impaired ($p < 0.05$); however, the degree of impairment was not as great as during cold weather (21% vs 76% below baseline). All other performance measures (handgrip, step test, pull-ups) demonstrated no significant differences.

High-Speed Boats

The first rendezvous to administer the performance measures was at the approximate halfway point of the transit in Georgetown, SC. As recounted by the participants, the sea conditions were difficult and resulted in a relatively consistent battering of the boats and operators. Comparison of the Georgetown data with baseline data (Fig. 3) demonstrated that manual dexterity was significantly impaired ($p < 0.05$). Results of the step test also indicate a significant decrement in performance ($p < 0.05$). Handgrip strength and pull-ups remained consistent when compared with baseline measurements. When comparisons of the data collected in Jacksonville, FL were made to baseline data, a pattern emerged that was different from any previously seen (Fig. 4). While only pull-up data were significantly different ($p < 0.05$) from baseline, the trend in three of the four measurements was in the opposite direction from most changes seen to date. Manual dexterity and the step test show slight improvement when compared with baseline data. Handgrip strength is the only measurement that remains constant when compared with baseline data.

Parachute Operations

This training operation was divided into two categories for the purpose of data collection: 1) day-jump training and 2) night-jump training. As mentioned previously, operators subjectively considered night jumps to be much more stressful than day jumps. The data collected after a day jump reflected no significant changes (Fig. 5) in any of the physical

measures. In addition, there did not appear to be any trends when comparing post-jump measurements to baseline data. Measurements obtained after night jumps (Fig. 6) demonstrated improvements in handgrip strength ($p < 0.05$), step test ($p < 0.05$) and pull-up performance ($p < 0.05$). While manual dexterity appeared to suffer after a HAHO jump, these data are not significantly different from baseline.

SDV Operations

The data collected during SDV training operations were obtained on a relatively small group of volunteers from the British SBS Support Squadron. Because of the small sample size and lack of uniformity of dive duration, data are presented as the performance of individual operators rather than a group mean. Post-dive data are still presented as a percentage of baseline. During each SDV excursion, one operator was assigned to be the pilot and the other operator assigned to be the navigator for the entire dive duration. In Fig. 7 dive days 1 and 2 were operations involving a 60/40 breathing gas mixture. Dive days 3 and 4 were AIR dive days. On days 2 and 4 the manual dexterity (Fig. 7) of the pilot was impaired, with performance reduced dramatically on day 4 when the gloves of the pilot leaked throughout the dive. Manual dexterity of navigators was reduced on days 1, 3, and 4. Hand grip strength (Fig. 8 and 9) was measured in both hands prior to and after SDV dives. When handgrip strength was measured in the pilots, the data demonstrated that on three of four days the dominant hand (which was used to steer the boat) suffered greater decrements in strength than the non-dominant hand. The same pattern was not evident in the navigators. The step test and pull-ups (Fig. 10 and 11) produced little in the way of differences that could be related to job assignment or length of dive. (The large percentage change on day 4 was due to a small change in absolute performance.) None of the

physical measures were significantly affected by the differences in breathing gas (Fig 7-11). Data collected on three Safety Boat subjects (SUB 1-3) did not demonstrate any patterns of reduced physical performance after exposure during SDV operations (Fig. 12). On the contrary, Safety Boat operators appeared to have maintained their physical capabilities during all four days of exposure.

SUMMARY

As with measures related to cognitive performance (8), there does not appear to be a consistent pattern of decrements in physical performance as a result of a variety of environmental stressors. Different patterns are evident during different operational conditions.

Not surprisingly, the extended cold stress of winter warfare training produces decrements in fine motor skills and strength of the hands and arms while not adversely affecting activities involving the legs. It should not be surprising that well-conditioned operators who spend a large part of their training day on skis can perform well on the step test.

The stress of extended land warfare training also produces distinctive patterns of performance decrements related more to fine motor skills than to decrements related to large muscle group strength or endurance.

The environmental stressors (incessant shock, vibration, and exposure to cold air and water) related to high-speed boat operations again appear to impact fine motor skills first, as well as strength, mobility, and coordination of the lower body. What is evident when comparing the relative stress of the first several days of the high-speed boat trip with the last days is the high level of conditioning that allows most operators to recover, even while under some environmental stress. As a result, performance decrements evident in Georgetown, SC were not

compounded by the remainder of the training trip. On the contrary, performance recovered back to and slightly above baseline.

Although considered to be more stressful, night-jump training appears to augment some physical capabilities, while having only a minimal negative impact on manual dexterity. Examination of additional night-jump exercises could help to document the duration of these performance improvements. Additional documentation should also note that this phenomenon may have a negative side. The questions could be asked: 1) What happens when the heightened physiological performance stimulated by the night jump subsides? 2) Are operators then at a disadvantage?

Performance measurements obtained during SDV operational training dives demonstrated that even shorter duration missions expose operators to environmental stressors that can affect performance. Manual dexterity and handgrip strength may in many cases be related to mission specialization, both from a positive and a negative standpoint. Decrements in performance of large muscle groups do not appear to be influenced by the duration and constraints of the SDV dives monitored in this study. Issues yet to be resolved include the following: What will be the results when performance is measured after much longer dives under more severe conditions? How do thermal protective garments and other equipment play a role in attenuating or accelerating performance decrements?

The primary goal of this project was to select an initial battery of physical measures sensitive to changes in performance that resulted from a variety of environmental stressors. In order to accomplish this goal, validation of the sensitivity and reliability of these measures are of paramount importance.

The data presented in this report have demonstrated the following:

1) The selected measures have met the criteria to be considered sensitive and reliable under multiple operational conditions.

2) Improvements that enhance the sensitivity and validity of the test battery can be implemented based on the results contained in this report.

3) The ability to assemble a completely independent, field-portable evaluation system relevant to operational maneuvers has been demonstrated.

These are certainly not the definitive measures of mission-related performance. Important issues which should be considered important are as follows:

1) This test battery must continually be refined by addition or subtraction of tests that could be more or less sensitive during specific operational scenarios. Addition of the shooting skills test will greatly enhance the ability to assess capabilities essential to all Special Forces operators.

2) Further refinement of other tests already a part of the test battery will increase their utility as quantifiers of mission-related performance.

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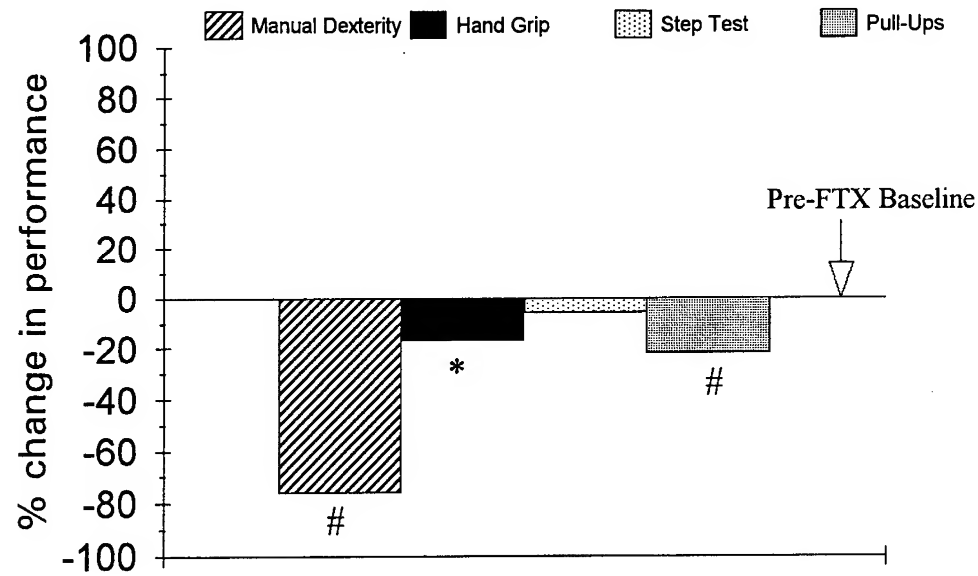

Fig. 1. Changes in physical performance after winter warfare Field Training Exercise (FTX). # = P < 0.01, * = P < 0.05.

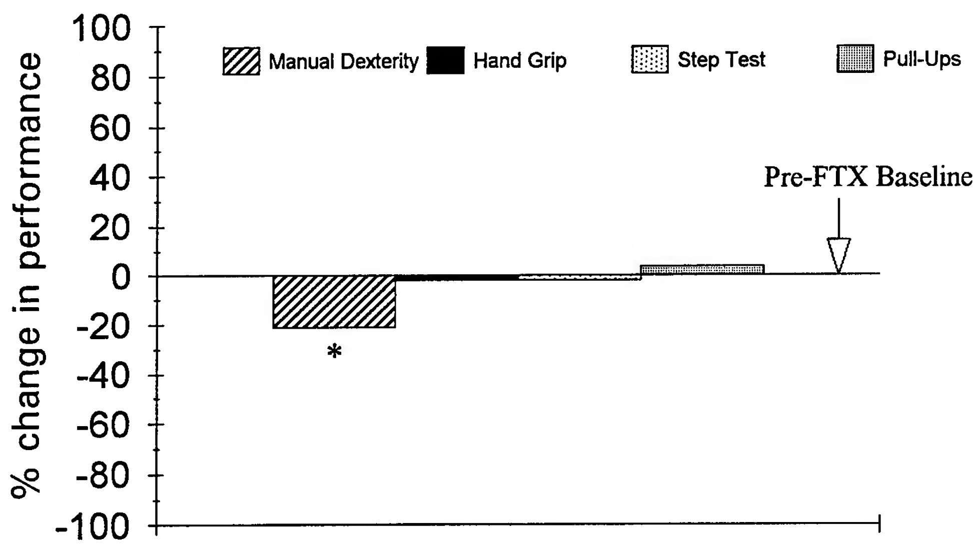

Fig. 2. Changes in physical performance after land warfare Field Training Exercise (FTX). * = P < 0.05.

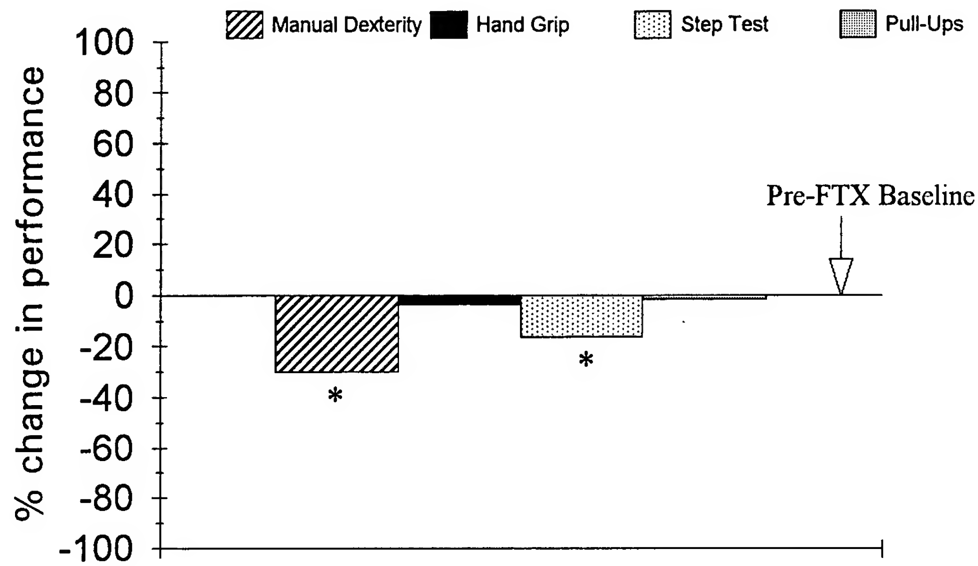

Fig. 3. Changes in physical performance after high-speed boat operation Field Training Exercise (FTX), Georgetown location
* = P < 0.05

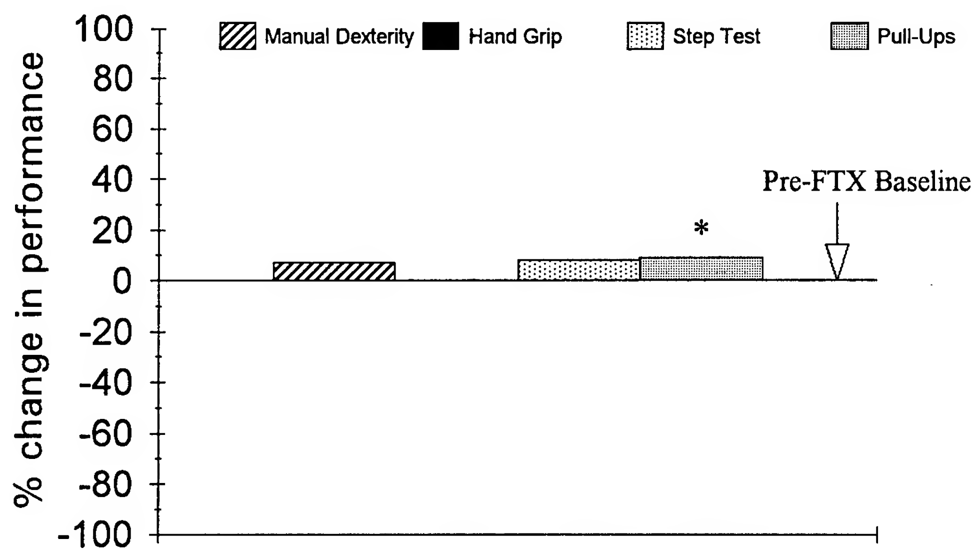

Fig. 4. Changes in physical performance after high-speed boat operation Field Training Exercise (FTX), Jacksonville location.
* = P < 0.05.

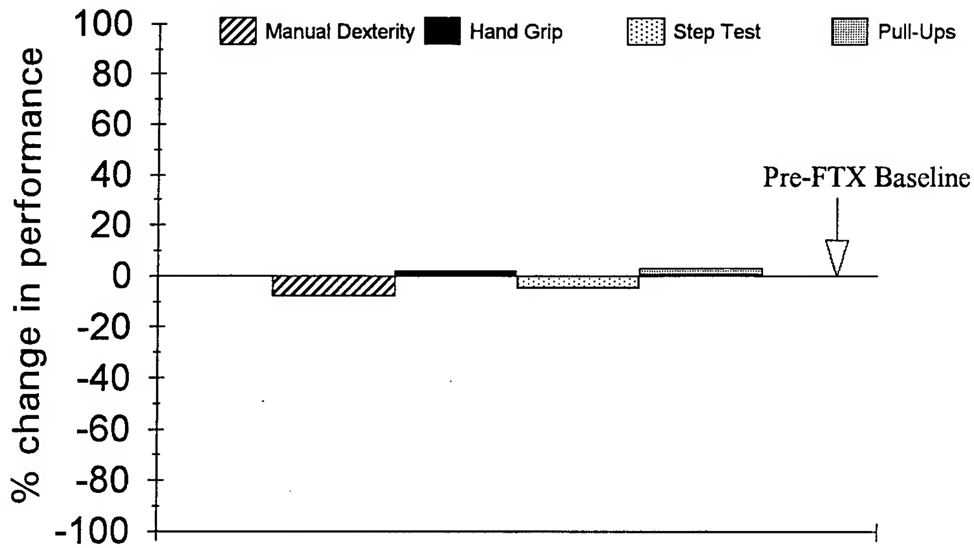

Fig. 5. Changes in physical performance after parachute Field Training Exercise (FTX), day-jump operation.

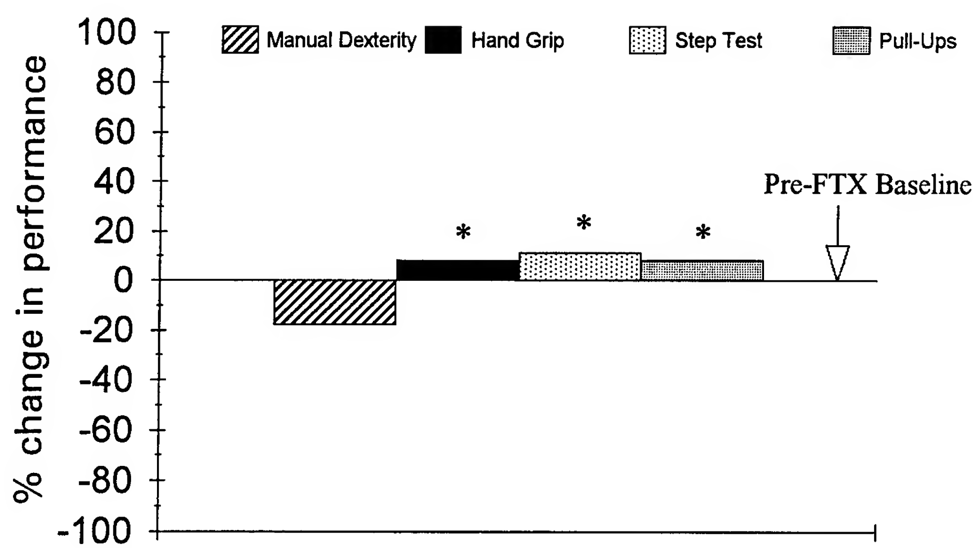

Fig. 6. Changes in physical performance after parachute Field Training Exercise (FTX), night-jump operation.
$* = P < 0.05$

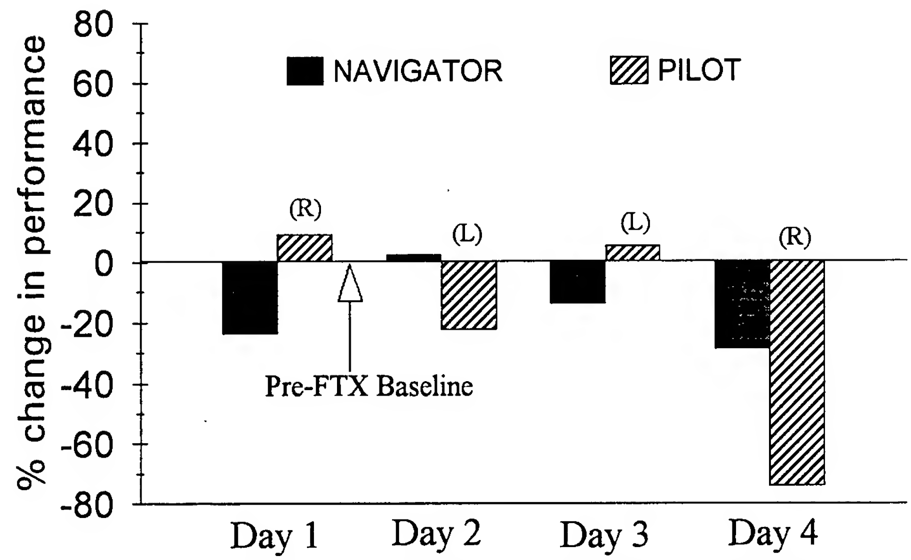

Fig. 7. Change in manual dexterity during SDV dives. (R) = right-handed, (L) = left-handed, FTX = field training exercise.

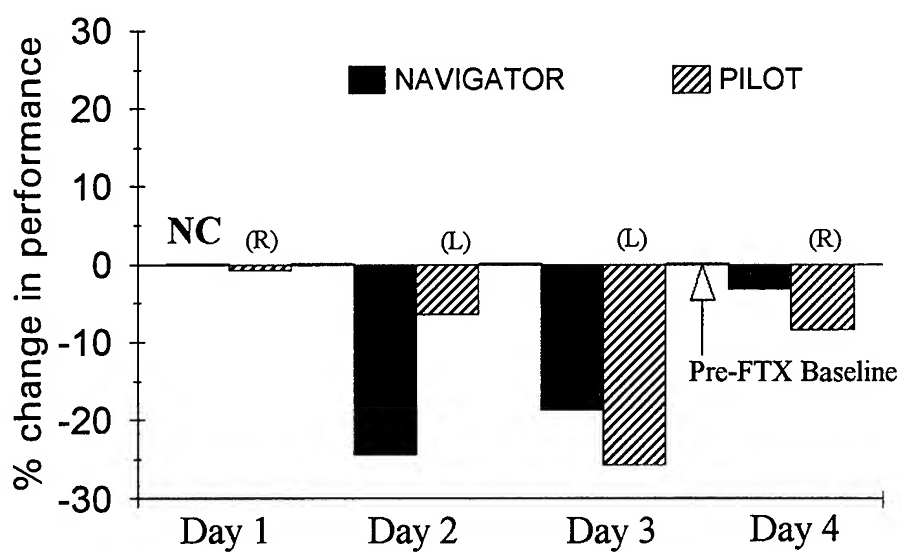

Fig. 8. Change in left hand grip strength during SDV dives. NC = no change in performance, (R) = right-handed, (L) = left-handed, FTX = field training exercise.

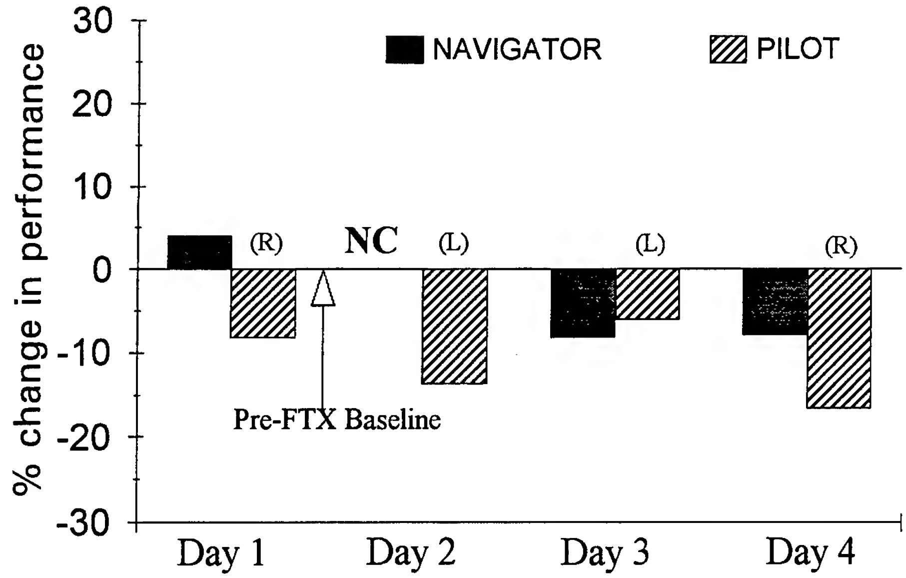

Fig. 9. Change in right hand grip strength during SDV dives. NC = no change in performance, (R)= right-handed, (L) = left-handed, FTX = field training exercise.

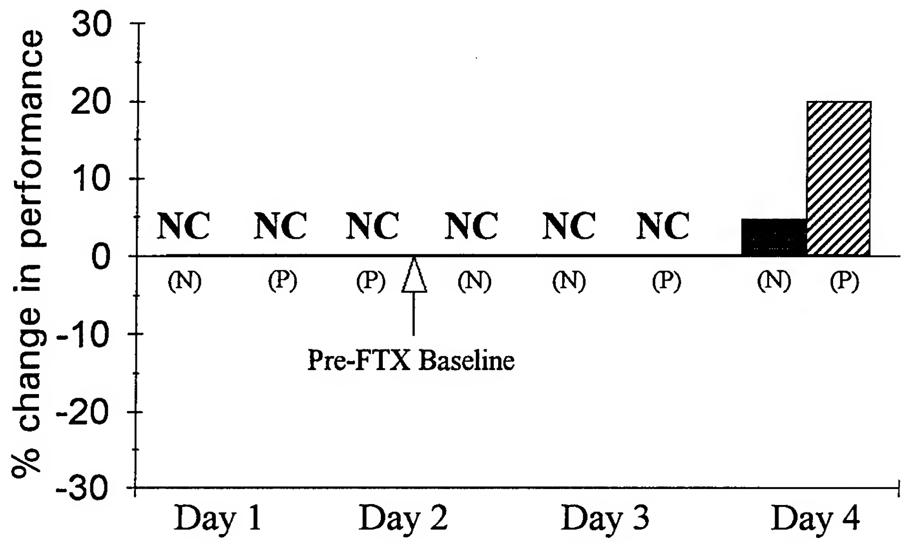

Fig. 10. Change in step test during SDV dives. NC = no change in performance, (P) = pilot, (N) = Navigator, FTX = field training exercise.

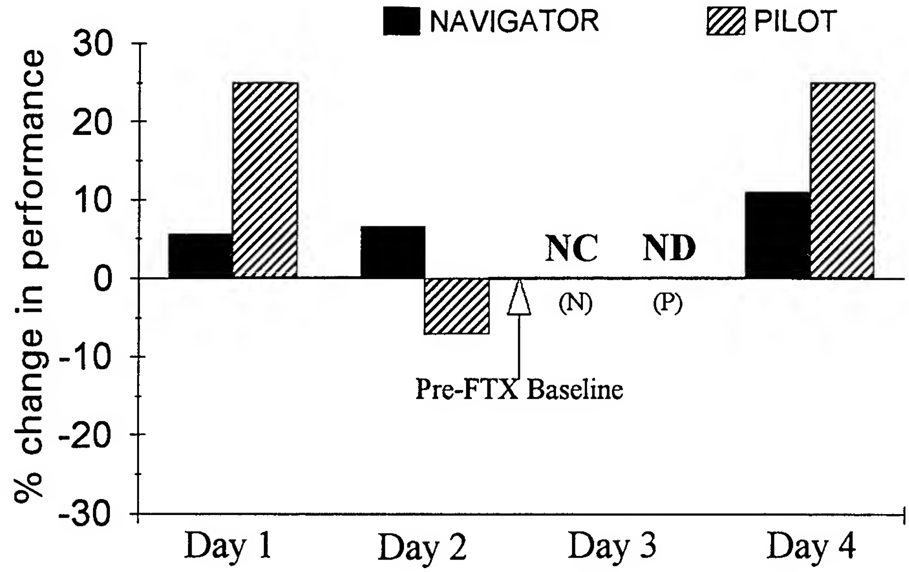

Fig. 11. Change in pull-ups during SDV dives. (P) = pilot, (N) = Navigator, NC = no change in performance, ND = no data due to injury, FTX = field training exercise.

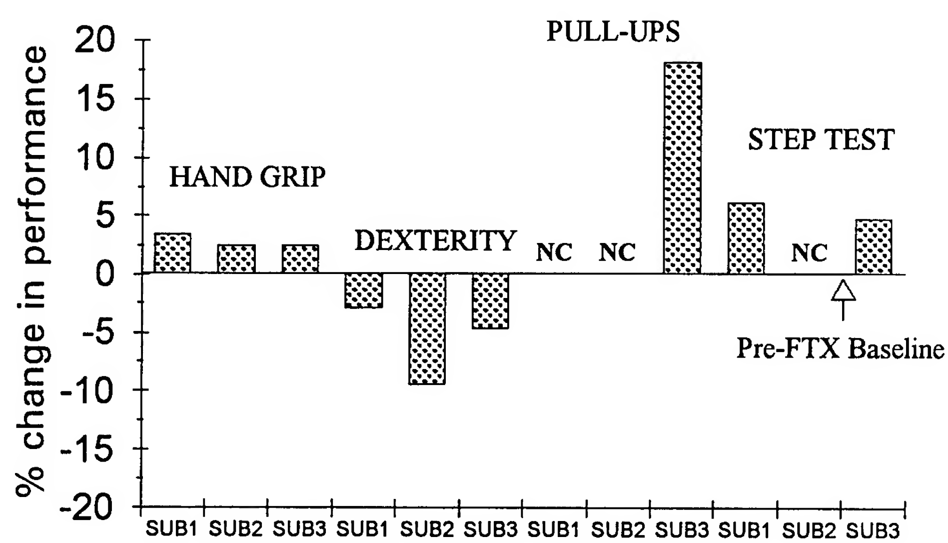

Fig. 12. Changes in performance of Safety Boat crew during SDV dives. NC = no change, FTX = field training exercise, SUB = subject.